Collision detection algorithm

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For many years, collision detection has been of major interest in robotics and computer graphics [→ Computer graphics]. Numerous approaches have been investigated to detect interfering objects in applications such as robot task planning, computational biology, games, surgery simulation, and cloth simulation. The central physical concept is spatial exclusion, i.e. the fact that two physical objects cannot occupy the same spatial location.

In the context of virtual computer-simulated objects, the spatial exclusion principle must be implemented through specific algorithms. Consequently, collision detection algorithms (CDA) are developed to avoid the interpenetration of two or more virtual objects.

The CDA depend on the type of objects and the type of their computer representation. They have been first developed in the context of perfectly rigid objects of which the computer models are based on geometry for the shape and direct cinematic for the motion. Consequently the central processes of the CDA are the computation of impact points and impact times, from the geometry and the cinematic of the objects. From these extracted data, movements after collision are programmed, through the computation of the velocity and acceleration vectors after the collision. When the computer representations of motion shifted from cinematic representations to physically based representations, the movement after collision is based on the computation of force applied to objects at the contact point and at the contact instant [Lin et al. 1997] [Redon et al. 2002].

From the rigid bodies framework, techniques evolved progressively by introducing deformable objects as soft objects are frequent in surgery simulation [Teschner et al. 2005].

Many methods for collision detection of the contact points are based on bounding volume hierarchies. The main idea is to partition the set of object primitives recursively until some leaf criterion is met. Some other widely used algorithms are based on spatial subdivision, stochastic methods, and distance field or image-space technique. While a large number of methods are developed for general or semi-general cases, some other methods are also designed for fast collision detection in special cases with some pre-known geometrical limitations.

The detection of the instant point in cinematic based approaches is mainly based on sample rate adaptation and time forward. So saying, they are not on-line oriented. Conversely explicit physically-based approaches [→ Physically-based modelling], are based on the on-line computation of the collision forces at each time sample.

In the context of the haptic rendering [→ Haptic rendering of virtual objects], the purpose of collision detection is not only to check collisions between objects, but more frequently to check collisions between the probe(s) of the haptic device and the virtual objects to compute the interaction forces. It is the elementary basic core of the human-computer enactive interaction. It consists in considering the haptic device as an external non-virtual object. In the hard real time context imposed by haptic interaction between human and virtual objects, collision detection algorithms become a hard bottleneck to overcome, the processes to detect contact and time points being highly demanding in term of computer load.

In the typology of exemplary enactive tasks as presented in [Luciani et al. 2006], the collision detection problem appears as a

critical bottleneck. The complexity and computer load of CDA increases drastically, when the expected interaction between users and physical objects is more and more tangible such as in case of strong enactive interaction. It increases also drastically in spatially-oriented manipulation tasks such as those in CAD (computer aided design) mechanical design, in mechanical maintainability as necessary in industrial applications (mechanics, aeronautics), or in surgery, in which the density of number objects and the density of variable objects are greater than in exploration and navigation tasks in large virtual environments. Such types of interactive tasks are characterized by:

- a high density of objects: very small free space ; highly confined scenes or dense maze.
- a high variety of objects with various mechanical functions, behaviours and shape: rigid well shaped components, deformable parts, wires, tubes, etc.

Real time optimization CDA techniques are then a main component of virtual reality systems and for the future are identified as a major bottleneck of enactive interfaces, linked to object scene local complexity and to the morphological complexity of the probe of the haptic device in tactile and in force rendering.

References

[Lin et al, 1997] Lin M., Manocha D., Cohen J., Gottschalk S. (1997) Collision Detection: Algorithms and Applications, in Proc. of Algorithms for Robotics Motion and Manipulation, pp. 129-142, 1997.

[Luciani et al, 2006] Luciani A., Magnusson C., Carozzino C., Boerck J., Mansa I., Preusche C.,, Jansson G., Kim H.S., Summers I., Khatchatourov A., Trestino (2006) Examplary Enactive Tasks and Associated Technological Bottlenecks, 2 ENACTIVE Workshop. Montreal. Mc Gill University

[Redon et al, 2002] Redon S., Kheddary A., Coquillart S. (2002) Fast Continuous Collision Detection between Rigid Bodies, in Computer Graphics Forum (Eurographics), vol. 21, no. 3, pp. 279–288, 2002.

[Teschner et al, 2005] Teschner M., Kimmerle S., Heidelberger B., Zachmann G., Raghupathi L., Fuhrmann A., Cani M.-P., Faure F., Magnenat-Thalmann N., Strasser W., Volino P. (2005) Collision Detection for Deformable Objects, in Computer Graphics Forum, vol. 24, no. 1, pp. 61-81.

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